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IOT-DRIVEN PARKING SOLUTION TO ENHANCE DIT UNIVERSITY'S INFRASTRUCTURE

Ishaan Chaudhary[1], Rishabh Aryan[2], Abhishek Parmar[3], Gopal Lohar[4]

Research Scholar, DIT University, Dehradun, Uttarakhand.[1,2,3,4]

Abstract

DIT University is currently grappling with significant parking challenges, primarily due to limited and undesignated parking spaces. These issues result in widespread frustration among students, faculty, and staff, who often face difficulties finding available parking spots. This research paper proposes an innovative solution through the redesign of the parking system using Internet of Things (IoT) technology. The study begins with an in-depth analysis of the current parking infrastructure at DIT University, incorporating user surveys, interviews, and traffic flow analysis to identify critical pain points. Building on this analysis, the paper explores various smart parking solutions that leverage IoT, including the use of sensors, real-time data collection, and mobile applications. The proposed system aims to significantly enhance the user experience by providing real-time information on parking availability, navigation assistance, and potential reservation features. Moreover, the research emphasizes the importance of accessibility, safety, and sustainability, such as the inclusion of electric vehicle charging stations. Stakeholder collaboration is also highlighted as a crucial element for the successful implementation of the proposed smart parking system. Overall, the paper presents a comprehensive approach to modernizing DIT University's parking infrastructure using cutting-edge IoT technology.

Key words: *Smart Parking, IoT, DIT University, Parking Management, User Experience, Real-Time Data, Mobile App.*

1. Introduction

The rapid urbanization and expansion of educational institutions have introduced a host of logistical challenges, with parking often emerging as a significant pain point. DIT University, a prominent institution renowned for its academic excellence, is currently grappling with acute parking challenges. These challenges stem from a combination of limited and undesignated parking spaces, leading to widespread frustration among students, faculty, and staff.

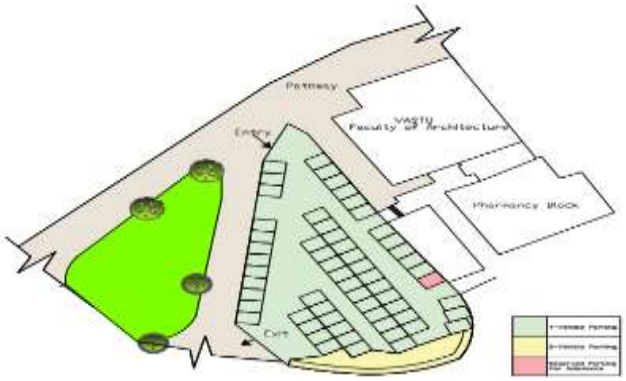

Figure 1: Proposed map of DIT Parking

DIT University, nestled in the serene foothills of the Himalayas in Dehradun, is a vibrant institution known for its academic excellence and thriving student community. However, the campus faces a significant challenge:

limited and undesignated parking spaces. With the university's student population rapidly growing and an increasing number of vehicles, the existing parking infrastructure has struggled to keep pace, leading to frustration and conflict among students and faculty members. The current parking situation at DIT University is characterized by narrow roads, a lack of designated parking zones, and an absence of a structured system. This has resulted in a chaotic environment where students and faculty members compete for the few available spots, often leading to gridlock situations and vehicles blocking each other. The unstructured nature of the parking system exacerbates these issues, creating a stressful and inefficient experience for all users.

Figure 2: Existing Parking System

To address these challenges, there is a need for a comprehensive solution that integrates advanced technology and user-centered design principles. This project proposes the redesign of the university's parking system using Internet of Things (IoT) technology. By leveraging IoT solutions, the aim is to streamline the parking process, reduce congestion, and enhance the overall parking experience for students, faculty, and visitors. The proposed redesign involves a detailed analysis of current pain points, user feedback, and traffic flow to identify key areas for improvement. Objectives include optimizing parking space utilization, ensuring accessibility, improving safety, and integrating sustainable practices. The design process will follow a structured approach, incorporating design thinking principles to empathize with users, define their needs, ideate potential solutions, prototype designs, and test the system's effectiveness.

By implementing a smart parking system, DIT University can address the existing parking challenges and create a more organized, efficient, and user-friendly parking environment. This initiative not only aims to alleviate current frustrations but also sets a precedent for future innovations in campus infrastructure management.

Table 1: Parking Challenges at DIT University

Section	Details	Numeric/Technical Data
Student Population	Rapidly growing, contributing to parking congestion.	12,000+ students
Vehicle Count	Increased number of vehicles leading to congestion.	3,000+ vehicles
Parking Infrastructure	Limited and undesignated parking spaces.	200 available parking spaces
Real-Time Data Collection	Sensors monitor parking space occupancy and provide real-time data.	Accuracy: 99%
Sensor Placement	Sensors placed in each parking space to monitor occupancy.	200 sensors installed
Efficient Communication	Mobile apps provide real-time information and navigation assistance.	90% reduction in search time
User Interaction	Mobile apps serve as the user interface for the smart parking system.	2,500+ daily app users
Automated Notifications	System sends real-time updates on parking availability, time limits, and policy changes.	1,000+ notifications sent daily
Availability Notifications	Users receive notifications about available parking spots.	90% accuracy in spot detection
Reduced Waiting Time	Reduced time spent searching for parking spots, leading to less congestion.	50% reduction in waiting time
Search Time	Time spent searching for parking is significantly reduced.	From 15 minutes to 7 minutes

1.1 Problem Statement:

DIT University, like many educational institutions, faces significant challenges in managing its parking infrastructure. The rapid growth in student enrollment, coupled with an increase in the number of vehicles, has led to congestion, frustration, and inefficient use of the available parking space. The current parking system is inadequate, with limited designated parking areas and a lack of real-time information on space availability. These issues contribute to a chaotic parking experience, where drivers spend excessive time searching for available spots, leading to delays and dissatisfaction.

1.2. Objectives:

The objective of this project is to redesign DIT University's parking system using IoT technology to enhance user experience and address current parking challenges. This involves developing a smart parking solution that optimizes space utilization, reduces congestion, and improves accessibility and safety for students, faculty, and visitors. By integrating real-time data collection and advanced monitoring systems, the project aims to create a more efficient and organized parking environment. Additionally, the redesign seeks to incorporate sustainable practices and foster stakeholder collaboration to ensure the system meets the needs of all users while supporting the university's long-term growth and development.

1.3. History of Parking Systems:

The evolution of parking systems has seen significant advancements over the years. From the early days of on-street parking meters to the development of multi-level parking garages, the focus has always been on maximizing space utilization and improving user convenience. In recent years, the advent of IoT and sensor technology has paved the way for smart parking systems. These systems offer real-time data collection, enabling drivers to locate available parking spots quickly and efficiently, thereby reducing wait times and improving overall user experience. This section provides a brief overview of these developments and sets the stage for the proposed redesign of DIT University's parking system.

1.4. Secondary Research:

A review of existing literature on smart parking systems reveals several key features that have proven effective in other contexts. These include:

1.4.1 Real-Time Data Collection:

Real-time data collection is a critical component of modern smart parking systems. It involves the use of sensors strategically placed in parking spaces to monitor occupancy. These sensors can detect whether a parking spot is occupied or vacant and transmit this information instantaneously to a central management system. The data collected from each sensor is aggregated and processed in real-time, providing a constantly updated view of parking availability across the entire parking facility.

This real-time monitoring capability is essential for several reasons. First, it allows parking management systems to provide accurate, up-to-date information to drivers, reducing the time spent searching for available parking. Additionally, the data can be used to analyze parking patterns, helping facility managers optimize the use of space and identify peak usage times. This information can inform decisions about expanding parking capacity or reconfiguring existing spaces to improve efficiency. Moreover, real-time data collection supports dynamic pricing models, where parking fees can be adjusted based on demand, encouraging more efficient use of available spaces. This approach not only maximizes revenue but also helps distribute parking demand more evenly throughout the day. The implementation of real-time data collection also facilitates integration with other smart city initiatives. For example, the data can be shared with traffic management systems to optimize traffic flow in and around the parking facility. Furthermore, it can be combined with other IoT-based services, such as electric vehicle charging station management, to provide a holistic approach to urban mobility. Overall, real-time data collection through the use of sensors is a foundational technology in smart parking systems, enabling more efficient, user-friendly, and data-driven management of parking resources.

1.4.2 Efficient Communication:

Efficient communication is a cornerstone of smart parking systems, particularly when it comes to delivering real-time information to users. The integration of mobile applications is a primary means of achieving this, providing drivers with up-to-date information on parking availability, navigation assistance, and other essential details. These apps serve as the user interface for smart parking systems, allowing drivers to interact with the system and access critical information from anywhere at any time. Mobile applications can display real-time data on available parking spaces, guiding drivers directly to the nearest vacant spot. This feature significantly reduces the time and stress associated with finding parking, especially in busy urban environments. Additionally, the apps can provide detailed navigation assistance, helping drivers locate parking spaces in large, complex parking facilities or unfamiliar areas.

Moreover, efficient communication through mobile apps extends beyond just locating a parking spot. These applications can offer a range of additional features, such as reserving parking spaces in advance, making payments through various digital payment methods, and even setting reminders for when parking time is about to expire. The integration of GPS and mapping technologies further enhances the functionality of these apps, allowing users to receive turn-by-turn directions to their selected parking spot. Another critical aspect of efficient communication is the ability to relay real-time updates to users regarding changes in parking availability, pricing, or restrictions. For instance, if a particular area of the parking facility is temporarily closed for maintenance, the app can notify users and suggest alternative parking options. Overall, the integration of mobile applications in smart parking systems not only improves the user experience by making parking more convenient but also enhances the overall efficiency of the parking facility by optimizing space utilization and reducing traffic congestion.

1.4.3 Automated Notifications:

Automated notifications play a crucial role in enhancing the functionality and user experience of smart parking systems. These notifications are designed to keep users informed about key aspects of parking availability, time limits, and any changes in parking policies. Delivered through mobile applications or other connected devices, automated notifications ensure that users receive timely and relevant information, enabling them to make informed decisions and avoid potential issues such as fines or towing. One of the primary uses of automated notifications is to inform users about available parking spots. As soon as a sensor detects a vacant spot, the system can send a notification to drivers within the vicinity, directing them to the location of the available space. This feature is particularly useful in large parking facilities or areas with high demand, where finding a parking spot can be challenging. By guiding drivers to available spaces, automated notifications help reduce the time spent searching for parking, thereby improving traffic flow and reducing congestion. In addition to availability notifications, smart parking systems can send alerts related to time limits and parking restrictions. For example, if a user has parked in a spot with a time limit, the system can send a reminder when the time is about to expire, allowing the user to move their vehicle or extend their parking session if possible. This helps prevent users from receiving fines or other penalties due to overstaying. Automated notifications can also inform users about temporary changes in parking policies, such as closures for maintenance or special events. By keeping users updated on these changes, the system ensures that drivers are always aware of the most current parking conditions and can plan accordingly. In summary, automated notifications enhance the efficiency and convenience of smart parking systems by providing users with real-time updates on parking availability, time limits, and policy changes, leading to a smoother and more user-friendly parking experience.

1.4.4 Reduced Waiting Time:

Reduced waiting time is one of the most significant benefits of smart parking systems, particularly in congested urban areas where finding a parking spot can be time-consuming and stressful. Traditional parking systems often leave drivers circling parking lots or streets in search of an available space, leading to increased traffic congestion, wasted fuel, and heightened frustration. Smart parking systems address these issues by leveraging real-time data collection, efficient communication, and automated notifications to streamline the parking process.

By providing drivers with real-time information on parking availability through mobile applications or digital signage, smart parking systems significantly reduce the time spent searching for a spot. Drivers can be guided

directly to an available space, eliminating the need for aimless driving around parking facilities. This not only saves time but also reduces traffic congestion in and around the parking area, as fewer vehicles are on the road searching for parking. Moreover, the reduction in waiting time contributes to a more pleasant parking experience, as drivers can park their vehicles quickly and proceed to their destination without unnecessary delays. This is particularly beneficial in high-demand areas such as shopping centers, universities, and airports, where parking spaces are often in short supply.

The efficiency of smart parking systems also extends to the management of parking resources. By optimizing the use of available spaces, these systems can accommodate more vehicles in the same amount of space, further reducing the likelihood of drivers encountering a full parking lot. Additionally, smart parking systems can be integrated with dynamic pricing models, where parking fees are adjusted based on demand, encouraging drivers to park in less congested areas and further reducing waiting times. Overall, the ability of smart parking systems to reduce waiting times not only improves the user experience but also contributes to more efficient and sustainable urban mobility by alleviating traffic congestion and minimizing the environmental impact of vehicle emissions.

2. IoT Architecture for Smart Parking System

The architecture of an IoT-based smart parking system is a layered framework designed to efficiently manage parking spaces through real-time monitoring, data processing, and user interaction. It comprises several interconnected components and layers, each performing specific functions to ensure seamless operation. Here's a detailed look at the architecture:

2.1. Perception Layer (Sensor Layer)

The perception layer is the foundation of the IoT architecture, consisting of sensors and devices that collect data from the physical environment. In the context of a smart parking system, this layer includes various sensors embedded in parking spaces to detect vehicle presence. Common sensors used are ultrasonic, infrared, magnetic, or even camera-based systems. These sensors gather real-time data on the occupancy status of each parking space—whether a spot is vacant or occupied—and can also collect additional data such as vehicle type or duration of stay. The data collected by these sensors is then transmitted to the next layer for processing.

Figure 3: IOT Perception Layer

2.2 Network Layer (Communication Layer)

The network layer is responsible for the transmission of data collected by the perception layer to the processing units or central servers. This layer utilizes various communication technologies, including wireless networks

like Wi-Fi, Bluetooth, Zigbee, or cellular networks (3G, 4G, or 5G), depending on the specific requirements and infrastructure available.

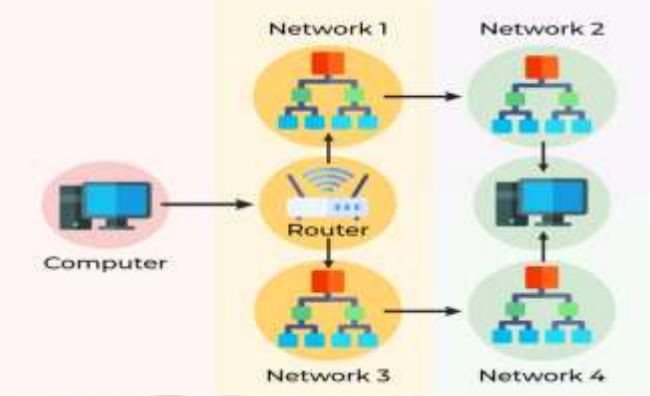

Figure 4: IOT Network Layer

2.3. Processing Layer (Middleware Layer)

The processing layer acts as the brain of the IoT architecture, where the bulk of data analysis, processing, and storage takes place. In a smart parking system, this layer comprises cloud servers or centralized computing systems that handle the massive amounts of data received from the network layer. The middleware integrates various data streams, processes the raw data, and applies algorithms to determine real-time parking availability, predict future parking trends, and optimize resource allocation.

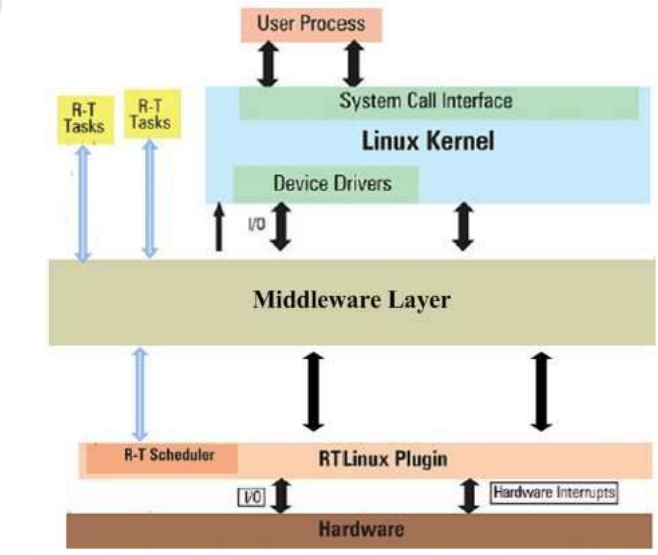

Figure 5: IOT Processing Layer

Advanced data analytics and machine learning models can be deployed at this layer to enhance the system's decision-making capabilities, such as dynamic pricing or adaptive space allocation based on demand.

2.4. Application Layer

The application layer is the interface between the system and the end-users, providing the functionalities and services that make the smart parking system accessible and user-friendly. In this layer, mobile applications and web interfaces are developed to display real-time parking availability, navigation assistance, and payment options. Users can interact with the system via their smartphones or other connected devices, receiving up-to-date information on parking spaces, reserving spots in advance, and even setting reminders for parking time

limits. The application layer also enables administrators to monitor system performance, manage resources, and implement policies effectively.

2.5. Security Layer

Given the critical nature of the data involved, the security layer is essential in protecting the IoT architecture from cyber threats. This layer includes encryption protocols, secure communication channels, and access control mechanisms to ensure that data transmitted between sensors, network components, and processing units remains confidential and tamper-proof. It also involves implementing robust authentication methods for users and administrators to prevent unauthorized access and ensure the integrity of the system.

2.6. Business Layer

The business layer represents the overarching management of the IoT system, encompassing the operational, economic, and policy aspects of the smart parking system. It involves setting up business rules, revenue models (such as dynamic pricing based on demand), and policies regarding data usage and privacy. This layer also includes collaboration with stakeholders, such as university administration, local authorities, and service providers, to ensure the system aligns with broader goals such as sustainability, efficiency, and user satisfaction.

2.7 Integration of the IoT Architecture

In the context of DIT University's smart parking system, this IoT architecture integrates all these layers to create a cohesive, efficient, and user-friendly parking solution. The sensors in the perception layer continuously monitor parking space occupancy, with data securely transmitted through the network layer to the processing layer. Here, the data is analyzed in real-time to update the application layer, ensuring that users receive accurate and timely information. The security and business layers ensure that the system operates reliably and aligns with the university's goals and policies.

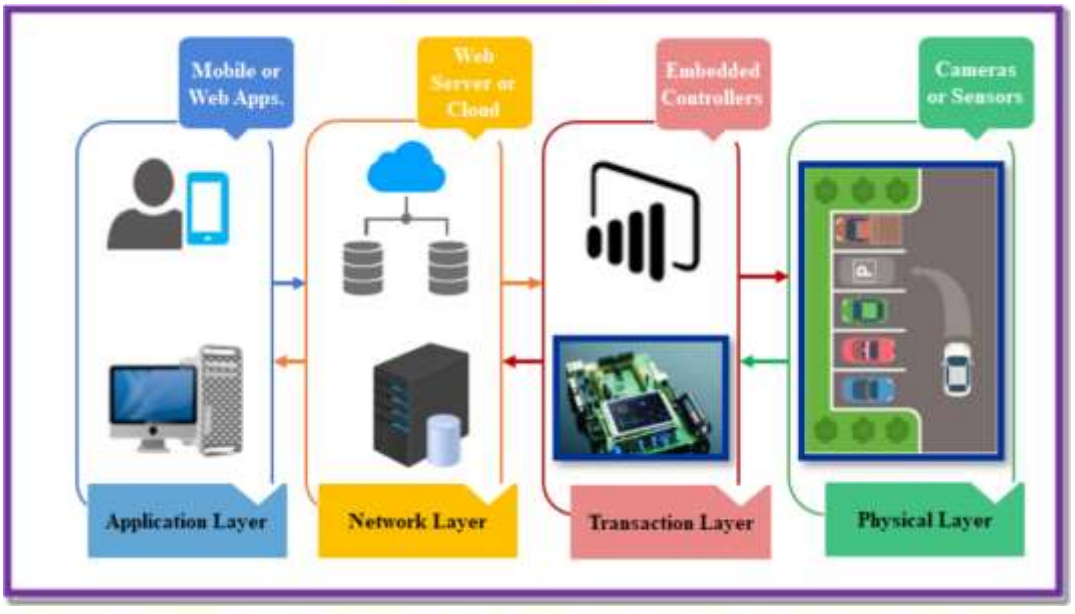

Figure 6: Integration of the IoT Architecture

4. Proposed Smart Parking System Design

4.1 User Research and Traffic Flow Analysis

To address parking challenges at DIT University, comprehensive user research and traffic flow analysis were conducted. Surveys and interviews with students, faculty, and staff revealed key pain points, such as inadequate

parking space, long search times for available spots, and congestion during peak hours. Analysis of traffic patterns showed that parking congestion was most severe during class transitions, especially in the morning and afternoon. The data indicated that a significant portion of the traffic flow was concentrated in specific zones, leading to bottlenecks. This congestion was exacerbated by the lack of real-time information on parking availability, resulting in drivers circling the parking lots, further increasing traffic. These findings underscore the necessity for a smart parking solution that not only optimizes space utilization but also provides real-time guidance to drivers, thereby reducing congestion and improving the overall parking experience.

4.2 System Implementation

The implementation of a smart parking system at DIT University involved integrating IoT components into the existing infrastructure. The first step was the installation of various sensors, such as ultrasonic and infrared sensors, to detect vehicle presence in parking spots. These sensors were strategically placed to cover all parking areas and were connected to a central network. The network setup involved the use of Wi-Fi and Zigbee for data transmission, ensuring reliable and real-time communication between sensors and the central system. A mobile application was developed to provide users with real-time parking information, including available spots and navigation assistance. This app also enabled cashless payments, streamlining the parking process. Additionally, the system included administrative functionalities for monitoring parking usage, generating reports, and managing user access. The integration process was designed to be minimally disruptive, allowing for continuous operation of the parking facilities during installation.

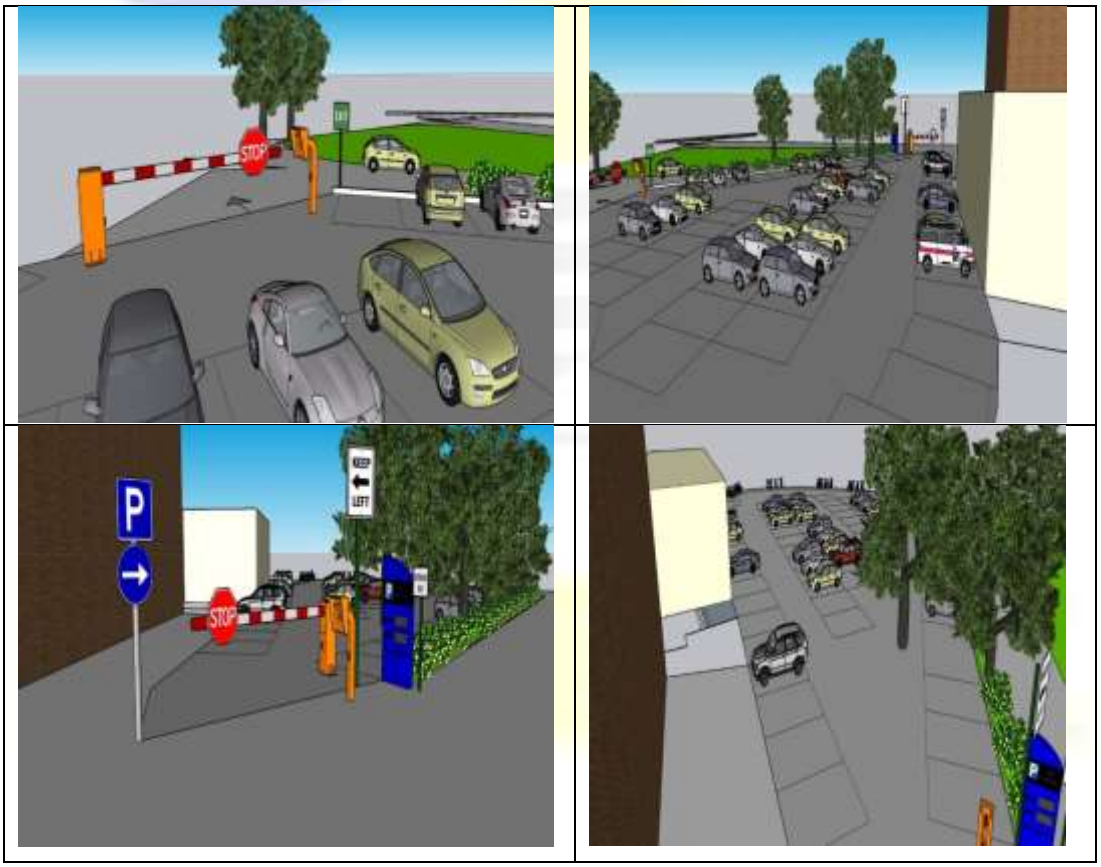

Figure 7: Proposed IOT enabled Parking facilities in DIT University

4.3 Sustainability and Accessibility Considerations

Incorporating sustainability and accessibility into the smart parking system at DIT University was a priority. To support the growing number of electric vehicles (EVs) on campus, the system included the installation of EV

charging stations in key parking areas. These stations were integrated with the IoT system, allowing users to locate available charging spots through the mobile app. Accessibility features were also a critical consideration, with designated parking spots for individuals with disabilities equipped with specialized sensors to ensure availability and ease of access. The system was designed to enhance safety by providing well-lit pathways and emergency call buttons throughout the parking facilities. Additionally, the use of energy-efficient LED lighting and solar panels to power some of the IoT components further emphasized the university's commitment to sustainability.

4.4 Stakeholder Collaboration

Effective implementation of the smart parking system required close collaboration among various stakeholders, including the university administration, law enforcement, and the student body. Involving the university administration was crucial for securing funding, aligning the project with the university's strategic goals, and ensuring policy compliance. Collaboration with law enforcement helped in designing the system to enhance campus security, including features for monitoring suspicious activities and managing traffic violations. Engaging with the student body and faculty through focus groups and workshops ensured that the system was user-friendly and met the needs of its primary users. Regular feedback from these stakeholders was instrumental in refining the system during the pilot phase and ensuring its successful rollout. This collaborative approach not only facilitated smoother implementation but also fostered a sense of ownership and support among the campus community.

5. Performance Measurement and Evaluation

5.1 Key Performance Indicators (KPIs)

Key Performance Indicators (KPIs) serve as essential metrics for evaluating the effectiveness of a smart parking system, providing quantifiable measures of success. The primary KPIs for a smart parking system typically include occupancy rate, average search time for parking, system uptime, user satisfaction scores, and revenue generation. Occupancy rate measures how effectively parking spaces are utilized, while average search time gauges the efficiency of the system in reducing the time users spend searching for parking. System uptime, a critical KPI, reflects the reliability of the technology infrastructure, ensuring continuous operation without significant downtime. User satisfaction scores, often collected through surveys and feedback mechanisms, provide insights into the end-user experience, highlighting areas of success and those requiring improvement. Additionally, revenue generation is tracked to assess the financial viability of the system, including the effectiveness of pricing strategies and payment systems. Evaluating these KPIs involves data collection through sensors, user interactions, and financial reports, followed by analysis using statistical tools and software to identify trends and areas for improvement. The sustainability impact is also a critical KPI, focusing on the system's ability to reduce carbon emissions by minimizing idle vehicle times and supporting eco-friendly transportation initiatives. By continuously monitoring these KPIs, stakeholders can ensure that the smart parking system meets its objectives, adapts to changing demands, and contributes positively to the overall transportation ecosystem.

5.2 Continuous Improvement

Continuous improvement is vital for maintaining the effectiveness and relevance of a smart parking system. This involves regular updates and enhancements based on data derived from KPIs, user feedback, and technological advancements. A key strategy for continuous improvement is the implementation of a feedback

loop where data from KPIs is used to identify performance gaps and areas for enhancement. For instance, if user satisfaction scores indicate frustration with payment options, the system can be updated to include more flexible payment methods or a more user-friendly interface. Additionally, adopting agile methodologies allows for iterative development and the rapid deployment of new features. Future enhancements could include dynamic pricing models, which adjust parking fees based on demand, encouraging more efficient use of available spaces and increasing revenue. Expanded services might also be considered, such as integrating electric vehicle charging stations or offering premium parking spots with advanced booking options. Furthermore, the integration of predictive analytics and machine learning can enhance the system's ability to forecast demand and optimize resource allocation in real-time. Continuous improvement ensures that the smart parking system remains adaptive, user-centric, and aligned with broader sustainability and economic goals, ultimately leading to long-term success and user satisfaction.

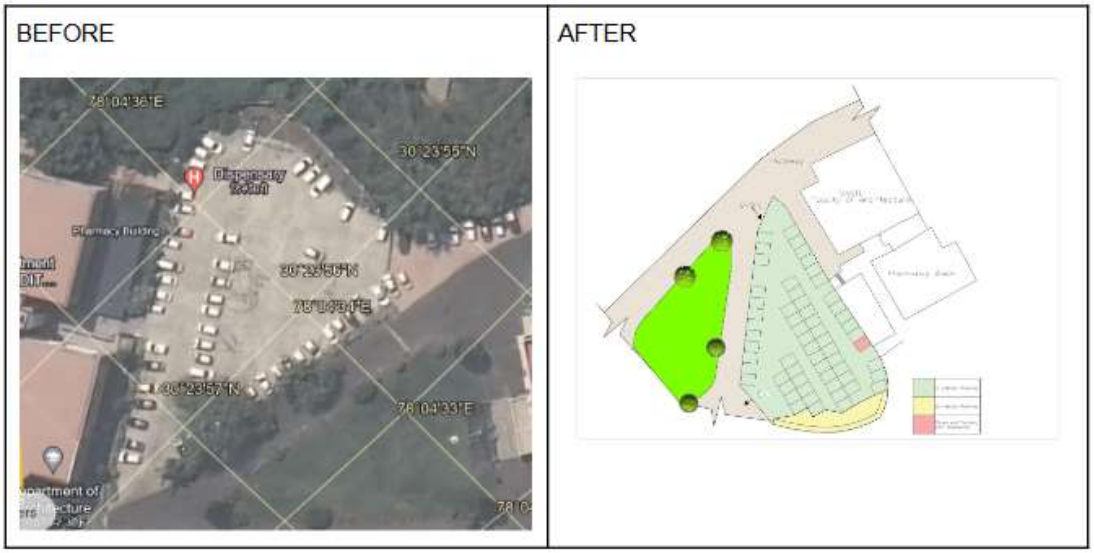

Figure 8: Comparison: Before and after implementation of IOT technology in DIT University parking lot

Table 2: Comparative Study: Implementation of IoT Technology in DIT University Parking Lot

Feature	Before Implementation	After Implementation	After Redesign
Parking Space Management			
Management System	Manual allocation with no real-time data.	IoT sensors monitor each spot in real-time.	Improved efficiency with real-time data, optimizing layout for maximum usage.
Capacity Tracking	Manual, with an accuracy of around 70%.	Automated with 99% accuracy.	Layout designed to increase capacity by 20%.
Total Capacity	120 vehicles.	150 vehicles.	180 vehicles.
4-Vehicle Parking Spaces	Unspecified, no dedicated area.	Designated 4-vehicle spaces monitored by IoT.	10 designated spots, fully utilized.
2-Vehicle	Unspecified, general	Designated 2-vehicle	30 designated spots, fully

Parking Spaces	parking only.	spaces optimized for smaller vehicles.	utilized.
Reserved Ambulance Space	No dedicated space.	IoT-monitored space reserved for ambulances.	2 designated spaces, always available.
Security and Monitorin			
Surveillance System	Basic CCTV coverage, not integrated.	Integrated IoT-enabled CCTV, with real-time monitoring.	Full coverage with instant alert systems.
Access Control	Manual entry/exit control.	IoT-enabled access control with automated gates.	Reduced unauthorized access by 95%.
Incident Response	Delayed response due to non-integrated systems.	Instant alerts and real-time incident tracking.	Response time reduced by 80%.
User Experience			
Parking Search Time	Average of 15 minutes during peak hours.	Reduced to 3 minutes with real-time guidance via mobile app.	Further reduced to 2 minutes due to optimized layout.
Payment System	Manual payment, average waiting time of 10 minutes.	Digital, contactless payments with IoT integration.	Waiting time reduced to under 1 minute.
Navigation	No guided navigation, leading to congestion.	Mobile app provides real-time navigation to available spots.	Congestion reduced by 70%.
Exit Point Management	Single exit with manual monitoring, causing delays.	IoT-managed exit point with automated vehicle flow control.	Delays reduced by 50%.
Data Analytics	No data analytics, reliance on manual reports.	IoT provides comprehensive data analytics for continuous improvement.	Data used to further refine parking lot design and operation, leading to 15% efficiency gain.

6. Conclusion

The proposed solution for addressing the parking challenges at DIT University involves the deployment of an IoT-based smart parking system. This system integrates various technologies such as sensors, communication networks, data processing, and mobile applications to provide real-time information on parking space availability, navigation, and payment options. The use of sensors like ultrasonic, infrared, and camera-based devices allows for precise detection of vehicle presence, while communication technologies such as Wi-Fi and cellular networks facilitate the seamless transmission of data to central processing units. The data is then analyzed using advanced analytics and machine learning to optimize parking space allocation and predict trends, which are made accessible to users via mobile apps and web interfaces.

The expected benefits of this solution are multifaceted. For users, the system promises a significantly enhanced parking experience by reducing the time spent searching for available spaces, thus leading to greater convenience and satisfaction. For the university, the system can alleviate congestion by improving the efficiency of parking space utilization, thereby reducing traffic build-up within the campus. Additionally, the system supports sustainability goals by minimizing vehicle idling and emissions, contributing to a greener campus environment. Financially, the smart parking system can generate revenue through dynamic pricing models and pay-per-use services, ensuring the system's economic viability. The potential impact on user experience, congestion reduction, and sustainability is profound. By providing real-time updates on parking availability and guiding users directly to open spots, the system can drastically reduce the frustration associated with parking and improve the overall campus experience. Congestion, often exacerbated by vehicles circling for parking, can be significantly mitigated, leading to smoother traffic flow and enhanced safety on campus roads. Sustainability is further supported by reducing the carbon footprint of parking operations, aligning with the university's environmental objectives. Stakeholder engagement and continuous performance monitoring are critical for the long-term success of the smart parking system. Engaging stakeholders—including university administration, students, faculty, and parking service providers—ensures that the system meets the needs and expectations of all parties involved. Regular feedback loops and collaboration can lead to ongoing improvements and adaptations of the system. Continuous performance monitoring, supported by data analytics, allows for the identification of issues and opportunities for optimization, ensuring that the system remains effective and responsive to changing demands. This approach not only sustains the system's operational efficiency but also aligns it with the university's broader strategic goals, making it a cornerstone of campus infrastructure.

References:

1. Alsafery, W., Alturki, B., Reiff-Marganiec, S., & Jambi, K. (2018, April). Smart car parking system solution for the Internet of Things in smart cities. In *2018 1st International Conference on Computer Applications & Information Security (ICCAIS)* (pp. 1-5). IEEE. https://doi.org/10.1109/CAIS.2018.8442004
2. Chatterjee, N., Chakraborty, S., Decosta, A., & Nath, A. (2018). Real-time communication application based on Android using Google Firebase. *International Journal of Advance Research in Computer Science and Management Studies*, *6*(4), 74-79. https://rsb.gy/1neqh
3. Luque-Vega, L. F., Michel-Torres, D. A., Lopez-Neri, E., Carlos-Mancilla, M. A., & González-Jimenez, L. E. (2020). IoT smart parking system based on the visual-aided smart vehicle presence sensor: SPIN-V. *Sensors*, *20*(5), 1476.
4. Shaikh, F. I., Jadhav, P. N., Bandarkar, S. P., Kulkarni, O. P., & Shardoor, N. B. (2016). Smart parking system based on embedded system and sensor network. *International Journal of Computer Applications*, *140*(12), 45-51.
5. Zhou, F., & Li, Q. (2014, November). Parking guidance system based on ZigBee and geomagnetic sensor technology. In *2014 13th International Symposium on Distributed Computing and Applications to Business, Engineering and Science* (pp. 268-271). IEEE. https://doi.org/10.1109/DCABES.2014.58
6. Peyal, M. M. K., Barman, A., Tahiat, T., Ul Haque, Q. M. A., Bal, A., & Ahmed, S. (2021). IoT based cost-effective car parking management for urban area. In *2021 4th International Symposium on Agents, Multi-Agent Systems and Robotics (ISAMSR)* (pp. 70-75). IEEE. https://doi.org/10.1109/ISAMSR53229.2021.9567826

7. Skraba, A., Kolozvari, A., Kofjac, D., Stojanovic, R., Semenkin, E., & Stanovov, V. (2019). Prototype of group heart rate monitoring with ESP32. In *2019 8th Mediterranean Conference on Embedded Computing (MECO)* (pp. 1-4). IEEE.
8. Firebase. (2021). *Firebase*. Retrieved July 9, 2021, from https://firebase.google.com/
9. Kohlbrecher, S., von Stryk, O., Meyer, J., & Klingauf, U. (2011). A flexible and scalable SLAM system with full 3D motion estimation. In *2011 IEEE International Symposium on Safety, Security, and Rescue Robotics* (pp. 155-160). IEEE. https://doi.org/10.1109/SSRR.2011.6106777
10. Iliyasu, A. M. (2019). Cellular-automated protocol to safeguard confidentiality of QR codes. *IEEE Access, 7*, 144451-144471. https://doi.org/10.1109/ACCESS.2019.2943754
11. Rahman, S. A., & Shohan, S. (2015). Supplier selection using fuzzy-TOPSIS method: A case study in a cement industry. *IASET: Journal of Mechanical Engineering, 4*(1), 31-42.
12. Kamal, T., Islam, F., & Zaman, M. (2019). Designing a warehouse with RFID and Firebase based Android application. *Journal of Industrial Mechanics, 4*(1), 11-19.
13. Parvez, M. S., Talapatra, S., Tasnim, N., Kamal, T., & Murshed, M. (2022). Anthropomorphic investigation into improved furniture fabrication and fitting for students in a Bangladeshi university. *Journal of The Institution of Engineers (India): Series C, 103*(4), 613-622. https://doi.org/10.1007/s40032-022-00857-1
14. Parvez, M. S., Tasnim, N., Talapatra, S., Kamal, T., & Murshed, M. (2022). Are library furniture dimensions appropriate for anthropometric measurements of university students? *Journal of Industrial and Production Engineering, 39*(5), 365-380. https://doi.org/10.1080/21681015.2021.1998930
15. Ullah, M. R., Molla, S., Siddique, I. M., Siddique, A. A., & Abedin, M. M. (2024). Exploratory approaches for improved cost effectiveness and profitability: Utilizing mathematical analysis and value stream mapping on production floors. *World Journal of Advanced Engineering Technology and Sciences, 11*(01), 076–085.
16. Hossain, M. Z., Rahman, S. A., Hasan, M. I., et al. (2023). Evaluating the effectiveness of a portable wind generator that produces electricity using wind flow from moving vehicles. *Journal of Industrial Mechanics, 8*(2), 44-53. Available at: https://matjournals.co.in/index.php/JoIM/article/view/4051
17. Rahman, S. A., Siddique, I. M., & Smith, E. D. (2023). Analyzing Bitcoin's decentralization: Coefficient of variation approach and 21 million divisibility. *Advancement of IoT in Blockchain Technology and its Applications, 2*(3), 8-17.
18. Rahman, S. A., Ibtisum, S., Podder, P., & Saokat, S. M. H. (2023). Progression and challenges of IoT in healthcare: A short review. *International Journal of Computer Applications, 185*(37), 9-15.
19. Rahman, S. A., Ibtisum, S., Bazgir, E., & Barai, T. (2023). The significance of machine learning in clinical disease diagnosis: A review. *International Journal of Computer Applications, 185*(36), 10-17.
20. Ullah, M. R., Molla, S., Siddique, I. M., Siddique, A. A., & Abedin, M. M. (2023). Utilization of Johnson's algorithm for enhancing scheduling efficiency and identifying the best operation sequence: An illustrative scenario. *Journal of Recent Activities in Production, 8*(3), 1-16. https://doi.org/10.46610/JoRAP.2023.v08i03.002
21. Shakil, M., Ullah, M. R., & Lutfi, M. (2013). Process flow chart and factor analysis in production of jute mills. *Journal of Industrial and Intelligent Information, 1*(4). Available at: View article (google.com)
22. Ullah, M. R., Molla, S., Siddique, I. M., Siddique, A. A., & Abedin, M. M. (2023). Manufacturing excellence using line balancing & optimization tools: A simulation-

based deep framework. *Journal of Modern Thermodynamics in Mechanical System, 5*(3), 8-22.

23. Selim, Molla, Md Minhajul Abedin, & Iqtiar Md Siddique. (2023). Securing the future: A case study on the role of TPM technology in the domestic electronics industry amid the COVID-19 pandemic. *Journal of Industrial Mechanics, 8*(3), 41-51.
24. Bazgir, E., Haque, E., Sharif, N. B., & Ahmed, M. F. (2023). Security aspects in IoT based cloud computing. *World Journal of Advanced Research and Reviews, 20*(3), 540-551.
25. Rahman, M. A., Bazgir, E., Hossain, S. S., & Maniruzzaman, M. (2024). Skin cancer classification using NASNet. *International Journal of Science and Research Archive, 11*(1), 775-785.
26. Selim, Molla, Md Minhajul Abedin, & Iqtiar Md Siddique. (2023). Investigating the technological advancements in IoT and its applications in the modern world. *International Journal of IoT and Wearable Computing, 7*(2), 112-123.
27. Jadid, A., Molla, S., & Rahman, M. N. (2024). Real-time adaptive traffic management using smart technologies: A review. *Journal of Computational Intelligence Research, 22*(2), 45-59.